

## ORIGINAL ARTICLES

### Impact of Palm Oil Processing Effluent Discharge on the Quality of Receiving Soil and River in South Western Nigeria

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#### ABSTRACT

The study was carried out to investigate the contribution of effluent from a palm oil processing unit on the receiving section of Oluwa River in Ondo State, Nigeria. Temperature, pH, COD, BOD<sub>5</sub>, major metals (NO<sub>3</sub><sup>-</sup>, PO<sub>4</sub><sup>-</sup>, K<sub>+</sub>, Na<sub>+</sub>, Mg<sub>2+</sub>) and heavy metals (Zn<sub>2+</sub>, Mn<sub>2+</sub>) as well as TS and TDS were determined in about 45 water samples obtained from various upstream and downstream locations away from the effluent discharge. Data obtained were subjected to statistical analyses of variance (ANOVA). Significant variations exist in most of the chemical variables among the sampled sections. Comparison of the investigated parameters at the various sections of the river with the standard limit of effluent guideline showed that the downstream water is polluted, especially in NO<sub>3</sub><sup>-</sup>, Zn<sub>2+</sub>, BOD<sub>5</sub> and COD. The need for a drastic move towards quality and environmental conservation through sustainable development and cleaner technology approach within manufacturing industries in Nigeria is highlighted.

**Key words:** palm oil effluent, water quality, soil, Nigeria

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#### Introduction

There is growing concern that agriculture, as fundamental as it is to the existence of man, is also responsible for many of the environmental ills facing the world today Hansen B., H.F. Alroe, E.S. Kristensen, (2001). Land degradation and loss of fertility caused by soil erosion is a major problem in Nigeria and other parts of the world. Agrochemicals, including chemical fertilizers and synthetic pesticides which have become an integral and indispensable component of modern agriculture, besides increasing production, are known to cause such negative side effects. These include eutrophication of fresh and marine waters, excessive nitrate leaching into ground water and the persistence of pesticide residues in food, soil and water. Similarly, processing of agricultural produce also contributes to pollution Patricia *et al.*, (1991). Food produce processing industries generate large quantities of effluent with a high Biochemical Oxygen Demand (BOD) which when discharged untreated into water courses and soil, adversely affects aquatic life, domestic water supply and land uses.

Oil palm cultivation and processing, like other agricultural and industrial activities, also raises environmental issues. Palm oil processing is carried out using large quantities of water in mills where oil is extracted from the palm fruits. During the extraction process, about 50% of the water results in palm oil mill effluent. It is estimated that for every 1 tonne of crude palm oil produced, 5-7.5 tonnes of water end up as palm oil mill effluent (POME) (Okwute, O.L, N.R Isu, 2007; Wu *et al.*, 2009). In major oil palm producing nations like Indonesia and Malaysia, production of crude oil results in an annual production of up to 3 billion pounds of palm oil effluent. As these effluents generally contain materials which at concentrations above threshold values Wu *et al.*, (2009) are injurious to the environment, it becomes necessary that effluent water should be treated or purified before being discharged into the environment.

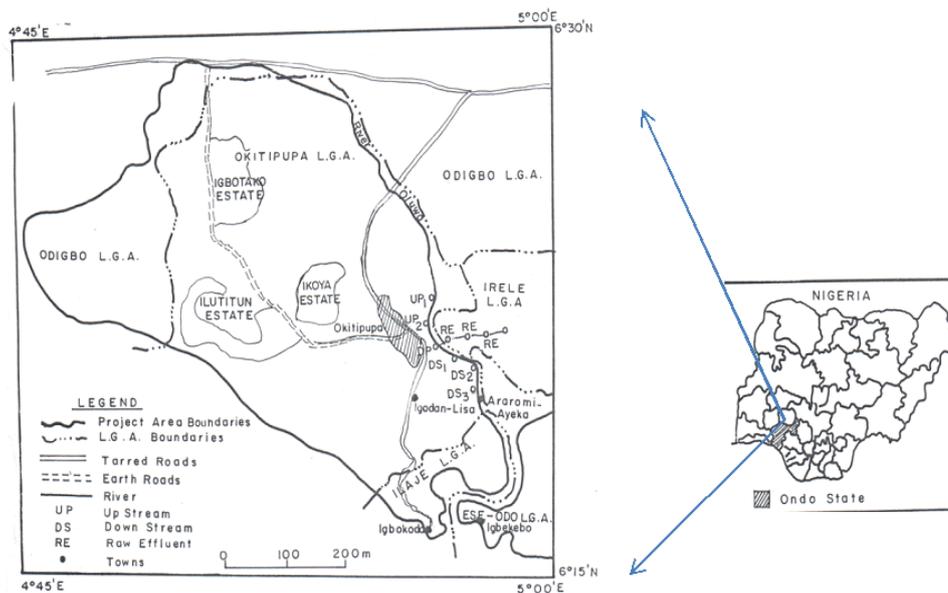
The process of oil palm processing in Nigeria is a routine procedure for most small scale operators. First the palm bunches are quartered (cut into four) and left overnight for easy separation of the nuts from the spikelet. The fruits are boiled for 1-1.5 hr, pounded in a mortar or macerated with feet in a canoe-like container; water is added and is well mixed up. All nuts are then carefully removed by hand. The fibres are

well-shaken over in the sludge, until oily foams come to the surface of the sludge. The foam is collected in a container until there is no more foam formation. The collected foam is later boiled for about 30 to 40mins. The clean edible oil then collects on the surface leaving the sludge at the bottom. Sometimes the oil in the sludge pit is recovered and mixed with fibre to make a fire starting cake called flint. At other times, the sludge is poured on the surrounding bushes and soil together with the liquid waste known as palm oil effluent. In Nigeria's palm oil industry, most of the POME produced by small scale traditional operators undergo little or no treatment and are usually discharged in the surrounding environment. This POME could pollute streams, rivers or surrounding land Okwute, O.L, N.R Isu, (2007). River water consequently turns brown, smelly and slimy. Often fish and other aquatic organisms get killed and local people are denied of the availability of local water sources for domestic uses and fishing Ezemonye *et al.*, (2008). The assessment of the possible ecological effects of effluents from oil palm industries on the environment through surveillance on the physico-chemical alterations caused by these discharged wastes are therefore of uttermost significance. Using Okitipupa Oil Mill as a reference point, the current study assesses the impact of palm oil processing effluent discharge on receiving soil and water quality in south western Nigeria

**Materials and Method**

*Sampling site*

A section along River Oluwa behind Okitipupa Oil Mill Plc in South Western Nigeria was considered for the study (Figure 1). This river directly receives regular discharge of wastes from the Oil Mill which is situated in Okitipupa town, the headquarters of Okitipupa Local Government Area of Ondo State, Nigeria. Using sterile containers and soil augers respectively, water and river-side soil samples were collected from upstream and downstream points on a section along the river.



**Fig. 1:** Map of study site

*Laboratory Analyses- SoilSamples:*

The collected soil samples were air-dried for seven (7) days. This was done to halt all the microbial activities in the soil. The air-dried samples were sieved using a 2mm sieve mesh size to remove debris and stones. The air-dried and sieved samples were used to analyze for various parameters.

*pH determination*

Ten grams (10g) of air-dried soil was weighed into two separate pH cups in ratio 1:2 (soil: 0.01M CaCl<sub>2</sub>) and 1:1 (soil: water). Twenty millimeters (20ml) of 0.01M CaCl<sub>2</sub> was added to ten grams (10g) of soil in one cup and the other cup with also ten grams (10g) of soil received ten millimeters (10ml) of distilled water. The

separate solutions were stirred continuously for about a minute for thorough mixing, and the solutions were left for about thirty minutes for the suspension to settle to bring the sample into solution. Then, the soil pH was measured using a pH meter. These results were reported as soil pH in 0.01M CaCl<sub>2</sub> and soil pH in water (H<sub>2</sub>O).

#### *Particle Size Determination:*

About 50g of dried soil by weight was dispensed in 100 ml of NaOH (Sodium Hydroxide). The preparation was placed on a reciprocal shaker for 4 hrs. The sample was poured into 1000 ml measuring cylinder and was made up to a 100ml mark with de-ionized water. It was plunged by the plunger severally after which the hydrometer was used to take the readings at 40 seconds. The second reading was taking after the soil solution was left for three hours (3 hrs). The temperature readings were recorded at the beginning (40 seconds) T<sub>1</sub> and at the end of three hours (T<sub>2</sub>). A blank sample containing a 100ml of NaOH was made up to a 100ml mark with de-ionized water as other samples. Sand, clay and silt properties were obtained using the following equations:

$$\text{Sand} = 100.0 - 2[(H_1 - B) + 0.2 (T_1 - 20^{\circ}\text{C})]$$

$$\text{Clay} = 2(H_2 - B) + 0.2 (T_2 - 20^{\circ}\text{C})$$

$$\text{Silt} = 100.0 - (\% \text{ Sand} + \text{Clay})$$

Where: H<sub>1</sub> and T<sub>1</sub> are Hydrometer and Thermometer reading respectively at 40 seconds, H<sub>2</sub> and T<sub>2</sub> are Hydrometer and Thermometer reading at the end of 3hrs.

#### *Available Phosphorus Determination:*

Two grammes of air-dried soil was weighed and dispensed in 20 ml of (0.025N HCl + 0.03N NH<sub>4</sub>F) solution, shaken for 5 minutes and then filtered. After filtration, 3ml of the preparation was put into a test tube, 3 ml of (0.87N HCl, 0.38N ammonium molybdate, 0.05% H<sub>3</sub>BO<sub>3</sub>) solution and 5 drops of (2.5g of 1-amino 2-tetraoxosulphate (vi) acid, 5.0g Na<sub>2</sub>SO<sub>3</sub>, 146g Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>) solution were sequentially added to the preparation. A colorimeter (at wave length of 660 nm) was then used to take readings.

#### *Total Nitrogen Determination:*

About 20 ml of concentrated tetraoxosulphate (VI) acid was added to a 1g measurement of air dried soil. A catalyst known as Kjeldahl TAB was also added and the solution was digested. After digestion, a clear solution was observed; this clear solution was distilled and subsequently titrated with 0.01M HCL

#### *Exchangeable Cations determination:*

About 100 ml of concentrated ammonium acetate was added to a 10gram measurement of air-dried soil and shaken for 30mins. The preparation was then filtered and taken to the flame analyzer for reading. Calcium, Sodium and Potassium were read on the flame photometer. Readings for Magnesium was obtained from a further titrated with sodium EDT A as flame photometers cannot be used.

#### *Organic Carbon Determination:*

With the use of a 10 ml bulb pipette, about 10 ml of potassium dichromate was added to a 0.5g measurement of air dried soil in a 500 ml conical flask. Twenty milliliters of concentrated tetraoxosulphate (VI) acid was equally added to the preparation in order to supply heat to the solution. It was then left for 30mins before diluting with about 200 ml of distilled water. Ten milliliters of H<sub>3</sub>PO<sub>4</sub> acid and 0.2g of sodium fluoride were also sequentially added to the preparation. Using a diphenylamine indicator, the preparation was back-titrated with concentrated ammonium ferrous sulphate to a greenish end point.

#### *Exchangeable Acidity Determination:*

Five grammes of air dried soil was weighed into 250ml of conical flask and about 50ml of Potassium Chloride was added. The preparation was stirred for 1 hr and then filtered. Another 50ml of KCl was added and shaken for 1 hr and was also filtered into 100ml volumetric flask to mark up to 1M KCl. Using a pipette,

about 50ml of the filtered preparation was dispensed into a 250ml conical flask. Using phenolphthalein indicator, the preparation was titrated with 0.01M NaOH into a pinkish end point. One or two drops of 0.01M HCl was added to the pinkish end point to bring it back to colourless, then 10ml of NaF was added to regenerate the faded colour, titration was done again with HCl until it was colourless, titration was done again with 0.01M HCl until it was colourless. The first value was a combination of Aluminum and hydrogen but the second value is hydrogen; the second value was subtracted from the first.

#### *Total Heterotrophic Bacteria and Fungi (THB, THF):*

One gramme of the soil/benthos sample was rehydrated with 10ml Sterile distilled water in a test tube containing some glass chips ( $10^1$ w/v) in the first instance. Using pour plate technique, aliquots from hundred folds serial dilution of the mixture were in triplicates plated on sterile nutrient agar already dispensed in petri dishes. These were incubated aerobically at 35°C for 36- 48 hours to enumerate for aerobes and facultative heterotrophic bacteria. The plates were observed for growth and selected for count after the expiration of the incubational period. After incubation, counts obtained from culture plates with less than 300 colonies were recorded. The average count observed at a particular dilution was multiplied by the dilution factor and expressed as the cell forming unit (CFU) per gramme of the original sample. Unlike the method used for total heterotrophic bacteria, spread plate technique was used for the estimation of Total Heterotrophic Fungi. Aliquots from hundred folds serial dilution of the mixture were in triplicates spread on the surface of sterile molten Malt Extract agar that has been allowed to set. The culture plates were incubated inverted at 30°C for 5 - 7 days (observed daily until the plate showed no further increase in the number of fungal colonies).

#### *Hydrocarbon Degrading Bacteria and Fungi (HDB, HDF):*

The same procedure for the THB was repeated for the total HDB. The culture medium however was replaced with sterile mineral salt medium (MSM) incorporated with 1.5% agar, 0.4% NaCl, 2% palm-oil (carbon source) and 10mg/L fungusol (Miconazole nitrate B.P 2%) at a final pH of 7.0. Culture plates were then incubated at room temperature or at 30°C for 7 -14 days. For enumeration of HDF, the culture medium was however replaced with sterile mineral salt medium (MSM) incorporated with 1.2% agar, 0.4% NaCl, 2% palm oil (carbon source), 50mg/L streptomycin (to inhibit bacterial growth) at a final pH of 4.5. Culture plates were incubated at room temperature or at 30°C for 16 -21 days.

#### *Laboratory Analyses – water samples:*

Water sample temperature was taken at the site of collection using a simple thermometer calibrated in °C, electrical conductivity was measured with a CDM 83 conductivity meter (Radio Meter A/S Copenhagen, Denmark). Dissolved Oxygen (DO) was determined using a digital DO meter. Turbidity and pH were determined at site using Water Proof Scan 3+ Double Junction (Wagtech International, UK) and HI 98311-HI 98312 (Hanna). Other physicochemical characteristics determined were hardness determined by titrimetry; total dissolved solid and total suspended solid were determined by gravimetric method; acidity, alkalinity and sulphate were determined by titrimetry; both nitrate and phosphate were determined colorimetrically by Spectronic 20 (Gallenkamp, UK) as earlier described AOAC International, (1998). Heavy metals were determined using atomic absorption spectrophotometer (Buck model 200A). As described by APHA, (1998), the 5-day dilution and incubation test was used to determine Biological Oxygen Demand (BOD). Titrimetric method was used for the determination of Chemical Oxygen Demand.

## **Results and Discussion**

Table I shows the different visual characteristics of the soil samples from the sites. The POME site (A) was observed to be bare without vegetation while the non- POME site (B) was grown with weeds. Due to the oil-palm effluent discharge noticeable in site A, the color of the soil was dark brown, damp and odiferous while that of the non – POME site (B) was observed to be brown, dry and free of odour. The POME site (A) was also covered with debris from the processing mill while that of the non-POME site B is filled with debris from leaves as it is for typical natural environments. Table II shows the silt, sand and clay content in the POME and non-POME sites Flood plain soil samples collected from the point of palm oil effluent discharge (A) showed marked variation in silt and sand content as compared with Point B and C which are downstream locations on the flow path of the discharged effluent. When these were compared with a control site located up to 100m away from the palm oil effluent discharge site, the clay content instead showed marked variation.

In the same vein, Table II shows a similar trend in the bulk density of all the points in the POME site which however varied slightly from that of the non-POME site. Physico-chemical parameters determined for the soil samples are presented in Table III. Soil acidity increased from point A to C in the POME sites while that of the non-POME site was observed alkaline. The result also shows an increase in the percentage organic matter, percentage carbon, percentage total nitrogen and available phosphorus from Point A to C of the POME site. Ordinarily one would expect dilution effect to bring about a reduction in the concentration of these parameters. However the possibility of further influx of domestic waste in addition to the industrial effluent could be the cause of this observed variance. The values of percentage organic matter, percentage carbon, and percentage total nitrogen for the non-POME site did not give a regular trend. However, they were generally lower or within the range of values recorded for upstream points on the POME site. Again, available phosphorus for the non-POME site was slightly lower than the least recorded for the POME site. For exchangeable cation, sodium values for both POME and non-POME sites remain constant. Table III shows an increase in the potassium, calcium, magnesium and ECEC ions from point A to C. For the non-POME site, the trend in the values of the cations is irregular. It records the lowest value for potassium, the highest value for calcium, and the lowest for magnesium and next to the highest for ECEC. The reason for this anomaly may also be traced to the downstream and midstream contributions of domestic waste to the already polluted watercourse.

Values obtained from the microbial counts of the soil samples from POME and non-POME sites are presented in Table IV. On the average, for each of the POME site, a higher population of the HDB was observed per colony forming unit of total heterotrophic bacteria as compared to the non-POME site where no effluent discharge was noticeable. This is understandable as oil-palm degrading bacteria thrive where there is abundance of the palm oil effluent substrate. A similar explanation obtains for the counts obtained for THF and HDF for all the sites. Generally, for every two colony forming units of total heterotrophic fungi, there was at least one with degrading potentials. A previous study Haimann, R.A., (1995) also attest to the unique saprophytic ability of fungi to grow on and degrade carbon sources in industrial effluents.

Table V and VI show the general chemical characteristics of the investigated effluent and the receiving water bodies at different course of the river. All the investigated parameters, except pH, electrical conductivity and dissolved oxygen were obtained at their highest concentration in the raw effluent samples, and highest in the upstream. Values obtained for pH, EC and DO were observed highest for upstream samples. This trend of occurrence is however not alarming because of the peculiarities of these pointers. Very high value of pH is known to be associated with alkalinity on the pH scale. The raw effluent samples were however more acidic than the rest of the investigated environment.

The result of the ANOVA and Schaffer multiple comparisons performed on the data (Table VII) showed that there was significant variation in the concentration of all the parameters investigated except EC, between the raw effluent and the upstream. This is also not unexpected as high concentration of the chemical variables is expected to be determined at the effluent source. The significant differences in temperature, pH, BOD<sub>5</sub>, Mg<sup>2+</sup>, Mn, Na<sup>+</sup>, SO<sub>4</sub> and PO<sub>4</sub> between the raw effluent and downstream could be attributed to the dilution effect on these parameters. It could also be inferred from Table VII that about same concentration of the raw effluent reached the discharge point from where it becomes diluted downstream.

Data presented in Table VII also reveal that the upstream may not have been totally free of some of these parameters, perhaps except for some of those that could be linked with pollution and sedimentation (BOD<sub>5</sub>, Total alkalinity, COD, TS and TDS). These parameters showed significant variation centres for the upstream and downstream samples. This result also agrees with the general perspective on the water bodies which are naturally mineralized, probably due to the influence of the underlying rock. However, further study may be required on the composition of the rocks to understand the role of such influence. The downstream and the discharge point however did not exhibit significant difference, within the consideration of any of the investigated parameters.

**Table 1:** Visual Characteristics of the Sites

Characteristics	Site A (Pome-Effluent Discharge Site)	Site B (Non Pome- Control Site)
Vegetation	Bare without vegetation	Grown with weeds
Colour	Dark brown	Brown
Moisture	Damp	Dry
Odour	Odiferous	Free of odour
Constitution	Debris processing mill	Debris from leaves

**Table 2:** Particle Size Analysis/ Textural Class

Sample Description	%Silt (g/kg)	%Sand (g/kg)	%Clay (g/kg)	Textural Class	Bulk Density (g/cm <sup>3</sup> )
PONT A	12	82	06	Loamy sand	1.66
PONT B	18	76	06	Loamy sand	1.65
POINT C	16	78	06	Loamy sand	1.66
POINT D	32	54	14	Loamy sand	1.49

Point A = Point of palm oil effluent discharge from the milling machine, Point B = mid stream of the palm oil flow path, Point C = downstream of the palm oil flow path, Point D = Control site (100m from the palm oil mill effluent site)

**Table 3:** Physico – chemical Parameters of Soil Samples

Parameters	A	B	C	D
Soil pH (CaCl <sub>2</sub> )	6.6	6.1	6.0	7.5
% Organic matter (mg g-l)	1.01	3.22	6.24	1.80
% Carbon (mg g-l)	0.59	1.86	3.63	1.05
% total nitrogen (mg g-l)	0.20	0.65	1.25	0.36
Available phosphorous (mg g-l)	4.80	5.20	5.60	4.50
EXCHANGEABLE CATION (cmol/kg)				
Na <sup>+</sup>	0.18	0.18	0.18	0.18
K <sup>+</sup>	0.15	0.32	0.50	0.12
Ca <sup>2+</sup>	0.80	2.10	2.70	4.70
Mg <sup>2+</sup>	0.80	1.60	3.80	0.40
ECEC	2.43	4.69	7.78	5.68
ACIDITY				
Al <sup>+</sup>	0.30	0.35	0.40	0.10
H <sup>+</sup>	0.20	0.18	0.18	0.18

Point A = Point of palm oil effluent discharge from the milling machine. Point B = mid stream of the palm oil effluent flow path. Point C = End point of the palm oil effluent flow path, Point D = Control site (100m away from the palm oil mill effluent site)

**Table 4:** Microbial count of the soil Samples

Sample Code	THB at 30°C (cfu/gm)	HDB at 30°C (cfu/gm)	THF at 30°C (cfu/gm)	HDF at 30°C (cfu/gm)
A	1.80 X 10 <sup>6</sup>	1.0 X 10 <sup>2</sup>	9.5 X 10 <sup>2</sup>	4.0 X 10 <sup>2</sup>
B	4.01 X 10 <sup>8</sup>	1.2 X 10 <sup>4</sup>	2.03 X 10 <sup>5</sup>	2.0 X 10 <sup>3</sup>
C	1.30 X 10 <sup>7</sup>	1.7 X 10 <sup>4</sup>	2.50 X 10 <sup>4</sup>	1.5 X 10 <sup>3</sup>
D	6.50 X 10 <sup>9</sup>	2.4 X 10 <sup>5</sup>	6.5 X 10 <sup>3</sup>	6.5 X 10 <sup>3</sup>

Point A = Point of palm oil effluent discharge from the milling machine, Point B = mid stream of the palm oil flow path, Point C = End point of the palm oil flow path, Point D = Control site (100m from the palm oil mill effluent site), THB =Total Bacteria, HDB = Hydrocarbon degrading Bacteria, THF = Total Fungi, HDF = Hydrocarbon degrading Fungi, Cfu = cell forming unit, Gm = grams

**Table 5:** Chemical characteristics of the raw effluent source, effluent discharge point and the receiving water body

Parameter	Sample Site	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
T°C	R	8	45.8875	5.0575	1.7881	38.60	52.30
	U	4	27.1000	2.9417	1.4708	24.20	30.60
	DO	8	36.0750	4.5703	1.6159	30.40	42.20
	DI	2	40.6000	6.3640	4.5000	36.10	45.10
pH	R	8	5.3400	.5427	.1919	4.80	6.20
	U	4	6.9750	0.05	0.25	6.90	7.00
	DO	8	6.6875	.3314	.1172	6.00	7.00
	DI	2	6.3000	.2828	.2000	6.10	6.50
EC	R	8	2.5125	.4486	.1586	1.80	3.10
	U	4	3.4375	1.8117	.9059	1.85	5.20
	DO	8	1.9913	.6305	.2229	1.40	3.40
	DI	2	1.9000	.4243	.3000	1.60	2.20
TA	R	8	121.6875	7.0457	2.4910	110.00	130.00
	U	4	55.1000	23.6928	11.8464	30.20	80.00
	DO	8	110.4625	8.7798	3.1041	100.20	120.10
	DI	2	113.6500	12.0915	8.5500	105.10	122.20
DO	R	8	1.2500	1.1032	.3901	.10	2.90
	U	4	6.6500	3.9315	1.9657	3.00	10.10
	DO	8	4.0038	2.9470	1.0419	.95	8.80
	DI	2	1.9750	1.5910	1.1250	.85	3.10
BOD <sub>5</sub>	R	8	123.6750	12.0678	4.2666	102.10	140.00
	U	4	74.1500	6.0819	3.0410	68.00	80.50
	DO	8	100.2875	10.6393	3.7616	88.10	115.00
	DI	2	107.6500	17.7484	12.5500	95.10	120.00
COD	R	8	284.7875	56.0870	19.8298	215.00	350.00
	U	4	70.2000	18.2587	9.1293	50.00	90.20
	DO	8	212.0500	69.5350	24.5843	140.10	290.00
	DI	2	251.0700	72.0825	50.9700	200.10	302.04
Mg	R	8	283.4625	62.6248	22.1412	202.20	365.10
	U	4	90.1250	29.4733	14.7367	60.00	120.10
	DO	8	175.9250	70.8738	25.0577	100.20	255.00
	DI	2	208.1500	127.3499	90.0500	118.10	298.20
Ca	R	8	252.4125	78.6156	27.7948	115.20	325.20
	U	4	91.3250	33.4267	16.7133	60.10	125.00
	DO	8	172.5750	79.4032	28.0733	85.20	262.20
	DI	2	197.4250	120.5264	85.2250	112.20	282.65
Zn	R	8	120.9500	27.7690	9.8178	90.10	150.20
	U	4	65.1500	14.5736	7.2868	50.10	80.00
	DO	8	106.2000	25.7115	9.0904	80.50	135.00
	DI	2	111.1000	36.7696	26.0000	85.10	137.10

**Table 5:** Continue

Fe	R	8	183.4950	40.3548	14.2676	140.20	229.10
	U	4	71.2800	16.4829	8.2414	55.10	90.00
	DO	8	147.5787	35.4444	12.5315	100.10	185.20
	DI	2	161.3750	44.2295	31.2750	130.10	192.65
Mn	R	8	34.2500	18.7977	6.6460	14.20	56.20
	U	4	4.7750	3.1732	1.5866	2.00	8.00
	DO	8	13.2963	7.0798	2.5031	5.00	22.02
	DI	2	18.0500	11.1016	7.8500	10.20	25.90
Na	R	8	332.2625	67.1408	23.7379	236.10	420.20
	U	4	83.9000	36.7799	18.3899	45.20	120.20
	DO	8	194.7375	61.9346	21.8972	125.20	255.00
	DI	2	205.3500	78.1353	55.2500	150.10	260.60

**Table 6:** Chemical characteristics of the raw effluent source, effluent discharge point and the receiving water body (continued)

Parameter	Sample Site	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
K	R	8	295.7375	73.8220	26.1000	200.10	380.20
	U	4	93.1250	16.1434	8.0717	72.20	110.10
	DO	8	201.7750	68.0812	24.0703	130.20	275.00
	DI	2	221.8000	98.4293	69.6000	152.20	291.40
Cl	R	8	198.6750	68.4804	24.2115	125.20	280.10
	U	4	57.6250	23.1914	11.5957	35.20	80.10
	DO	8	125.4125	28.4564	10.0609	80.20	155.60
	DI	2	138.7000	33.2340	23.5000	115.20	162.20
SO <sub>4</sub>	R	8	65.7500	30.8280	10.8993	30.20	102.20
	U	4	10.6000	6.5686	3.2843	5.20	20.00
	DO	8	31.3125	31.3118	4.7064	15.10	49.60
	DI	2	37.7000	17.6777	12.5000	25.20	50.20
NO <sub>3</sub>	R	8	262.2625	89.1548	31.5210	142.20	360.20
	U	4	69.9250	60.5340	30.2670	15.20	128.10
	DO	8	170.2300	75.0799	26.5447	80.20	245.00
	DI	2	188.1100	96.0392	67.9100	120.20	256.02
PO <sub>4</sub>	R	8	165.6500	45.9037	16.2294	102.20	216.10
	U	4	52.6000	40.4023	20.2012	15.20	90.00
	DO	8	97.7550	25.2734	8.9355	70.20	125.02
	DI	2	105.9500	29.3449	20.7500	85.20	126.70
TS	R	8	517.1125	129.7398	45.8699	350.20	650.50
	U	4	175.3250	33.9663	16.9831	140.50	220.10
	DO	8	453.2750	130.9544	46.2994	320.20	590.20
	DI	2	477.6500	187.3126	132.4500	345.20	610.10
TDS	R	8	274.1500	42.2986	14.9548	220.10	320.20
	U	4	120.2000	29.4173	14.7087	90.00	150.20
	DO	8	254.1375	44.2239	15.6355	210.20	298.20
	DI	2	259.1500	57.9120	40.9500	218.20	300.10
TSS	R	8	242.9875	87.5237	30.9443	130.10	330.30
	U	4	55.1500	12.8085	6.4042	40.10	70.00
	DO	8	199.1750	86.7552	30.67.26	110.00	292.00
	DI	2	218.6500	129.1884	91.3500	127.30	310.00

R: Raw Effluent , U: Upstream , DO: Downstream, DI: Discharge Point

**Table 7:** Results of the Analysis of Variance of Raw Effluents

Parameter	F value	F-probability	Raw Effluent			Upstream		Seasonal variance
			Upstream	Downstream	Discharge point	Downstream	Discharge point	
Temp	15.503	0.000	0.000	0.005	ns	0.044	0.030	0.029
pH	21.048	0.000	0.000	0.000	ns	ns	ns	ns
EC	2.623	ns	ns	ns	ns	0.000	ns	ns
TA	27.766	0.000	0.000	ns	ns	ns	0.000	0.02
DO	4.364	0.018	0.25	ns	ns	0.012	ns	ns
BOD <sub>5</sub>	18.197	0.000	0.000	0.006	ns	0.009	0.024	0.01
COD	12.130	0.000	0.000	ns	ns	ns	0.020	0.003
Mg	8.006	0.001	0.002	0.040	ns	ns	ns	0.000
Ca	4.139	0.021	0.025	ns	ns	+ns	ns	0.00
Zn	4.229	0.020	0.021	ns	ns	ns	ns	0.003
Fe	8.878	0.001	0.001	ns	ns	0.023	ns	0.000
Mn	5.879	0.006	0.014	0.036	ns	ns	ns	0.003
Na	15.730	0.000	0.000	0.003	ns	ns	ns	0.004
K	8.353	0.001	0.001	ns	ns	ns	ns	0.041
Cl	8.207	0.001	0.002	ns	ns	ns	ns	0.004
SO <sub>4</sub>	6.743	0.003	0.006	0.040	ns	ns	ns	0.007

**Table 7:** Continue

NO <sub>3</sub>	5.328	0.008	0.010	ns	ns	ns	ns	0.008
PO <sub>4</sub>	9.282	0.001	0.001	0.017	ns	Ns	ns	0.000
Ts	7.140	0.002	0.003	ns	ns	0.016	ns	0.004
TDS	12.859	0.000	0.000	ns	ns	0.001	ns	0.002
TSS	4.737	0.013	0.015	ns	ns	ns	0.13	0.008

F – Value is significant at  $p < 0.05$ , ns = variance not significant at  $p < 0.05$

Based on the aforementioned, imperative therefore is the need for the considered industry and related ones to aim at incorporating industrial effluents treatment schemes that reduce the amount of these potentially toxic compounds to their acceptable threshold limit value (TLV) according to standards of the World Health Organization and in more a localized sense; standards set by the Federal Environmental Protection Agency and the Department of Petroleum Resources (DPR) in Nigeria Igwe and Onyegbado, (2007). Worthy of note is the fact that most of the waste currently generated in Nigerian industries are either partially treated or not treated at all either because of negligence on the part of the industries or because of inexistent implementable regulation in this respect (Akande, 1994; Arunsi, 1993). This prevalent status quo is far from the desired as most industries in developed countries strive towards quality and environmental conservation through sustainable development and cleaner technology approach.

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